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CHARLES MILL RESERVOIR, ASHLAND AND RICHLAND COUNTIES, OHIO

Pacific Northwest Environmental Research Laboratory

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June 1975

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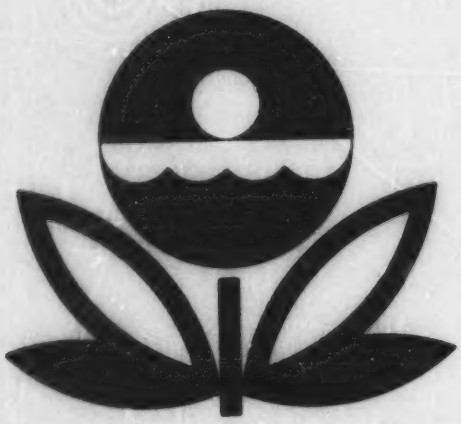
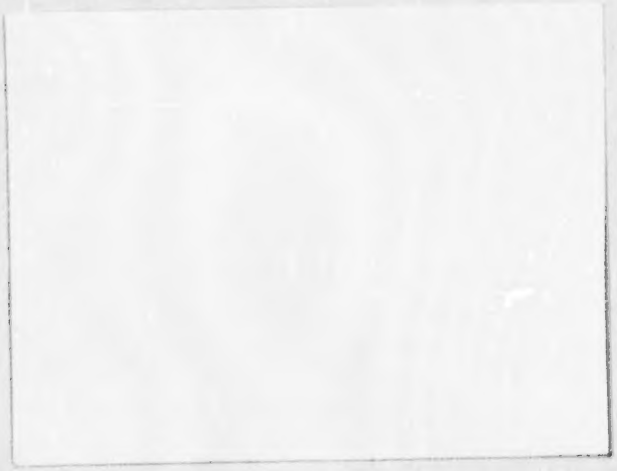
U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES





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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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Report
on
Charles Mill Reservoir
Ashland and Richland Counties
Ohio

EPA Region V

Working Paper No. 397

With the cooperation of the

Ohio Environmental Protection Agency

and the

Ohio National Guard

June, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Ohio Environmental Protection Agency for professional involvement, to the Ohio National Guard for conducting the tributary sampling phase of the Survey, and to those Ohio wastewater treatment plant operators who provided effluent samples and flow data.

Ned Williams, Director, and Tom Birch, Ken Carr, Larry Dietrick, Ron Havlice, Larry Korecko, Rod Mehlhop, Terry Wheeler, and John Youger, Ohio Environmental Protection Agency, provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

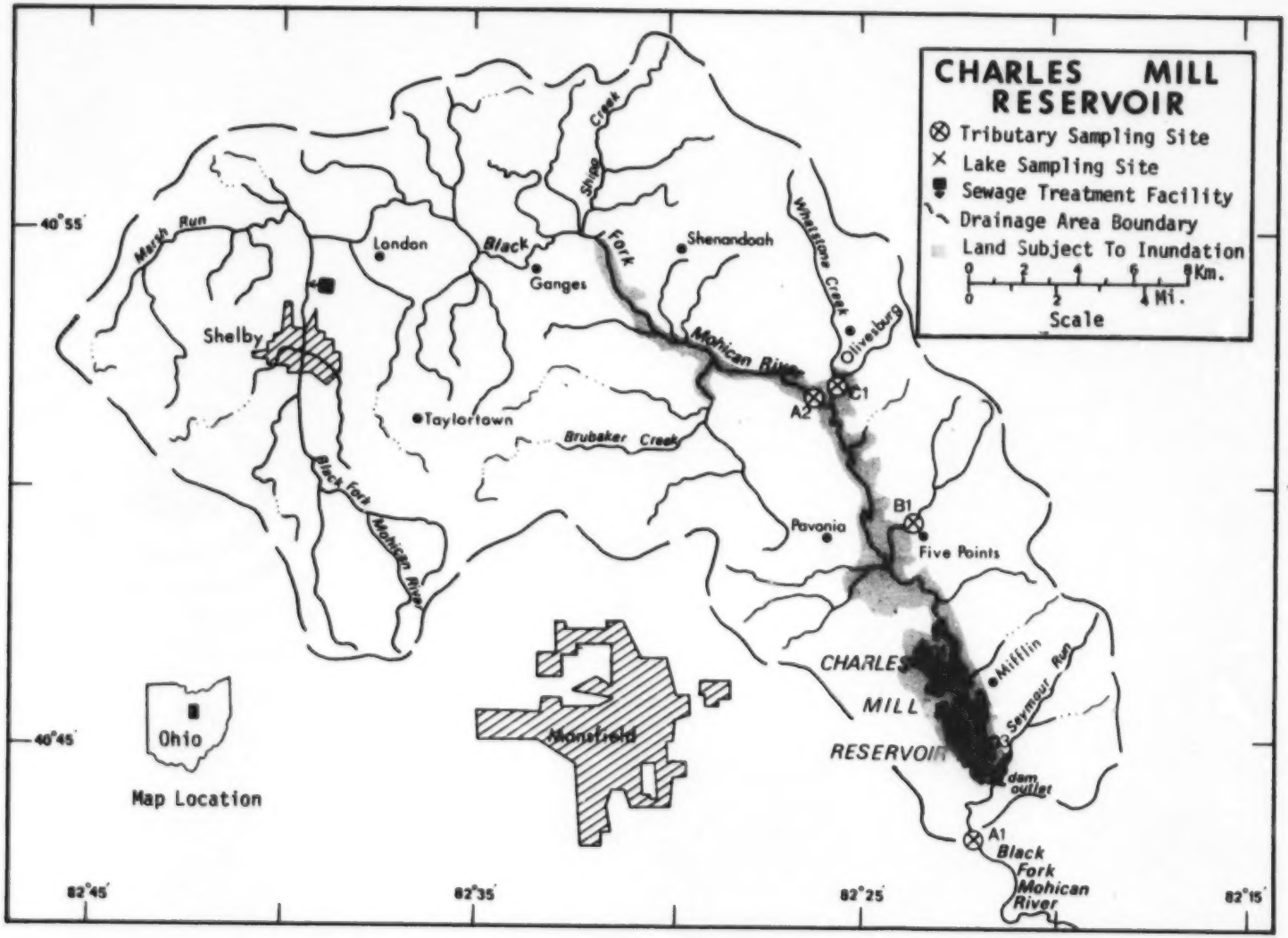
Major General Dana L. Stewart, then the Adjutant General of Ohio, and Project Officer Lt. Colonel Robert C. Timmons, who directed the volunteer efforts of the Ohio National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF OHIO

LAKE NAME	COUNTY
Atwood	Carroll, Tuscarawas
Beach City	Stark, Tuscarawas
Berlin	Mahoning, Portage, Stark
Buckeye	Fairfield, Licking, Perry
Charles Mill	Ashland, Richland
Deer Creek	Fayette, Pickaway
Delaware	Delaware
Dillon	Muskingum
Grand Lake of St. Marys	Auglaize, Mercer
Grant	Brown
Holiday	Huron
Hoover	Delaware, Franklin
Indian	Logan
Loramie	Auglaize, Shelby
Mosquito Creek	Trumbull
O'Shaughnessy	Delaware
Pymatuning	Ashtabula, OH; Crawford, PA
Pleasant Hill	Ashland, Richland
Rocky Fork	Highland
Shawnee	Greene
Tappan	Harrison


CHARLES MILL RESERVOIR
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
Land Subject To Inundation
0 2 4 6 8 Km.
0 2 4 Mi.
Scale
40°55'
40°45'
82°45'
82°35'
82°25'
82°15'
Marsh Run
London
Shelby
Black Fork Mohican River
Taylortown
Brubaker Creek
Ganges
Shiloh Creek
Shenandoah
Mohican River
Whetstone Creek
Olivesburg
A2
C1
Pavonia
B1
Five Points
CHARLES MILL RESERVOIR
Mifflin
Seymour Run
B3
dam outlet
A1
Black Fork Mohican River
Mansfield
Ohio
Map Location

CHARLES MILL RESERVOIR

STORET NO. 3905

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Charles Mill Reservoir is eutrophic. Of the 20 Ohio lakes sampled in 1973, it ranked sixteenth in overall trophic quality based on a combination of six water quality parameters*. Fourteen of the lakes had less median total phosphorus, eight had less median dissolved orthophosphorus, seven had less median inorganic nitrogen, 15 had less mean chlorophyll a, and 12 had greater mean Secchi disc transparency. Depletion of dissolved oxygen with depth occurred at station 2 in July.

Survey limnologists noted that the water was turbid on all sampling occasions except for station 2 in July.

Significant numbers of blue-green algae at all sampling times indicate an enriched condition (see page 6).

B. Rate-Limiting Nutrient:

The algal assay results show that Charles Mill Reservoir was phosphorus limited at the time the assay sample was collected (04/20/73). The reservoir data indicate phosphorus limitation in July as well but nitrogen limitation in October.

C. Nutrient Controllability:

1. Point sources--During the sampling year, point sources

* See Appendix A.

contributed 57.4% of the total phosphorus load to Charles Mill Reservoir. The wastewater treatment plant at Shelby contributed 38.6% of the load, and three other facilities at Imperial Estates, Eastview, and Crestwood Hills collectively contributed an estimated 18.6%. Septic tanks contributed an estimated 0.2%. In addition, a wastewater treatment plant at Ramada Inn of unknown nutrient significance is located in the drainage basin (see page 9).

Three industries also are located in the drainage but are not of nutrient significance (Youger, 1976).

The present phosphorus loading of 5.56 gm/m^2/year is over five times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 12). Although Vollenweider's model may not be applicable to water bodies with hydraulic retention times as short as 20 days, the present trophic condition of Charles Mill Reservoir is evidence of excessive nutrient loads. While even complete removal of phosphorus at the point sources would still leave a eutrophic loading, the reservoir is phosphorus limited much of the time, and all phosphorus inputs should be minimized to the greatest practicable extent to at least slow the present rate of eutrophication.

2. Non-point sources--Non-point sources contributed 42.6% of the total phosphorus input to Charles Mill Reservoir during the sampling year. The Black Fork of the Mohican River contributed 37.4%, Whetstone Creek contributed 1.5%, and Unnamed Creek B-1 contributed 0.4%. Minor tributaries were estimated to have contributed 3.0%.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 5.46 kilometers^2.
2. Mean depth: 1.7 meters.
3. Maximum depth: 9.4 meters.
4. Volume: 9.282×10^6 m^3.
5. Mean hydraulic retention time: 20 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Black Fk., Mohican River	375.5	3.7
Unnamed Creek B-1	21.5	0.2
Whetstone Creek	43.5	0.4
Minor tributaries & immediate drainage -	116.0	1.1
Totals	556.5	5.4

2. Outlet -

Black Fk., Mohican River	562.0**	5.3

C. Precipitation***:

1. Year of sampling: 107.6 centimeters.
2. Mean annual: 90.8 centimeters.

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† Table of metric conversions--Appendix B.
†† Youger, 1975.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Charles Mill Reservoir was sampled three times during the open-water season of 1973 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from three stations on the reservoir and from one or more depths at each station (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 0.9 meters at station 1, 8.2 meters at station 2, and 1.5 meters at station 3.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR CHARLES MILL RESERVOIR
STORET CODE 3905

	1ST SAMPLING (4/20/73) 3 SITES			2ND SAMPLING (7/27/73) 3 SITES			3RD SAMPLING (10/ 6/73) 3 SITES		
PARAMETER	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN
TEMP (C)	10.7 - 14.4	13.1	13.7	11.9 - 27.1	21.6	25.2	18.8 - 19.7	19.3	19.3
DISS OXY (MG/L)	7.8 - 14.1	10.9	10.9	0.0 - 9.4	3.6	3.2	6.6 - 9.4	8.1	8.4
CNDCTVY (MCROMO)	370. - 460.	406.	390.	365. - 427.	383.	378.	328. - 460.	369.	344.
PH (STAND UNITS)	8.2 - 8.9	8.5	8.5	7.2 - 8.7	7.9	7.9	7.9 - 8.3	8.1	8.1
TOT ALK (MG/L)	122. - 146.	129.	122.	115. - 192.	136.	132.	119. - 167.	136.	128.
TOT P (MG/L)	0.038 - 0.067	0.057	0.060	0.138 - 0.800	0.249	0.185	0.092 - 0.198	0.129	0.114
ORTHO P (MG/L)	0.006 - 0.008	0.007	0.007	0.010 - 0.028	0.016	0.016	0.011 - 0.018	0.013	0.011
NO2+NO3 (MG/L)	0.360 - 1.200	0.726	0.570	0.090 - 0.680	0.247	0.120	0.020 - 0.060	0.037	0.035
AMMONIA (MG/L)	0.040 - 0.150	0.061	0.050	0.070 - 4.600	0.766	0.170	0.060 - 0.090	0.070	0.065
KJEL N (MG/L)	0.580 - 1.200	0.857	0.800	1.200 - 7.600	2.356	1.700	1.300 - 2.080	1.550	1.450
INORG N (MG/L)	0.480 - 1.250	0.787	0.720	0.160 - 4.720	1.012	0.650	0.090 - 0.130	0.107	0.105
TOTAL N (MG/L)	1.160 - 2.030	1.583	1.600	1.500 - 7.720	2.602	1.880	1.320 - 2.080	1.587	1.485
CHLRPYL A (UG/L)	41.7 - 75.9	63.5	72.9	40.2 - 91.2	72.3	85.5	49.6 - 86.2	65.6	61.1
SECCHI (METERS)	0.5 - 0.8	0.6	0.6	0.3 - 0.4	0.3	0.3	0.3 - 0.6	0.4	0.3

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/20/73	1. Synedra sp.	8,183
	2. Flagellates	6,677
	3. Ankistrodesmus sp.	2,245
	4. Melosira sp.	1,655
	5. Stephanodiscus sp.	620
	Other genera	591
	Total	19,971
07/27/73	1. Stephanodiscus sp.	18,427
	2. Oscillatoria sp.	5,770
	3. Melosira sp.	4,793
	4. Nitzschia sp.	4,514
	5. Merismopedia sp.	2,885
	Other genera	9,259
	Total	45,648
10/06/73	1. Centric diatoms	17,119
	2. Melosira sp.	7,294
	3. Flagellates	4,615
	4. Oscillatoria sp.	3,771
	5. Raphidiopsis sp.	2,680
	Other genera	27,389
	Total	62,868

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
04/20/73	01	72.9
	02	75.9
	03	41.7
07/27/73	01	91.2
	02	40.2
	03	85.5
10/06/73	01	86.2
	02	49.6
	03	61.1

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.044	0.992	4.1
0.050 P	0.094	0.992	20.6
0.050 P + 1.0 N	0.094	1.992	24.2
1.0 N	0.044	1.992	3.8

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Charles Mill Reservoir was moderately high at the time the assay sample was collected (04/20/73). Also, a significant increase in yield with the addition of orthophosphorus alone indicates that the lake was limited by phosphorus at that time. Note that the addition of nitrogen alone resulted in a yield no greater than that of the control.

The lake data indicate phosphorus limitation in July as well; i.e., the mean inorganic nitrogen/orthophosphorus ratios were 35/1 or greater at all stations, and phosphorus limitation would be expected. However, the mean N/P ratios in October were 10/1 or less at all stations, and nitrogen limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Ohio National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of February and March when two samples were collected. Sampling was begun in May, 1973, and was completed in April, 1974.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Ohio District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in $kg/km^2/year$, at stations B-1 and C-1 and multiplying the means by the ZZ area in km^2.

The operator of the Shelby wastewater treatment plant provided monthly effluent samples and corresponding flow data. The operators of Imperial Estates, Eastview Sewer District #4, and Crestwood Hills Sewer District #4 did not participate, and nutrient loads were estimated at 1.134 kg P and 3.401 kg N/capita/year. The operator of the wastewater

* See Working Paper No. 175.

treatment plant at Ramada Inn also did not participate, but nutrient loads could not be estimated because the population served is not known.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Shelby**	10,000	act. sludge	4,868.0	Black Fk., Mohican River
Imperial Estates	2,000***	ext. aeration	757.0†	Unnamed Trib/ Charles Mill Reservoir
Eastview SD #4	2,400***	ext. aeration	908.4†	Black Fork, Mohican River
Crestwood Hills SD #4	600††	ext. aeration	227.1	Black Fork, Mohican River
Ramada Inn	?	ext. aeration	?	Unnamed Trib/ Black Fork, Mohican River

2. Known industrial* -

Three industries are located in the drainage basin but are not of nutrient significance.

* Youger, 1976.
** Burberry, 1974.
*** Population estimate based on 4 people/home.
† Estimated at 0.3785 m^3/capita/day.
†† Population estimate based on flow of 0.3875 m^3/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Black Fk., Mohican River	11,345	37.4
Unnamed Creek B-1	110	0.4
Whetstone Creek	460	1.5
b. Minor tributaries & immediate drainage (non-point load) -	910	3.0
c. Known municipal STP's -		
Shelby	11,710	38.6
Imperial Estates	2,270	7.5
Eastview SD	2,720	8.9
Crestwood Hills SD	680	2.2
Ramada Inn	?	-
d. Septic tanks* -	50	0.2
e. Known industrial -	not significant	-
f. Direct precipitation** -	95	0.3
Total	30,350	100.0

2. Outputs -

Lake outlet - Black Fk., Mohican River	25,060

3. Net annual P accumulation - 5,290 kg.

* Estimate based on town of Mifflin (served entirely by septic tanks), 82 shoreline dwellings, one park, and one camp area; see Working Paper No. 175.

** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Black Fk., Mohican River	347,220	69.9
Unnamed Creek B-1	10,585	2.1
Whetstone Creek	23,485	4.7
b. Minor tributaries & immediate drainage (non-point load) -	59,870	12.1
c. Known municipal STP's -		
Shelby	30,700	6.2
Imperial Estates	6,800	1.4
Eastview SD	8,160	1.6
Crestwood Hills SD	2,040	0.4
Ramada Inn	?	-
d. Septic tanks* -	1,895	0.4
e. Known industrial -	not significant	-
f. Direct precipitation** -	5,895	1.2
Total	496,650	100.0

2. Outputs -

Lake outlet - Black Fk., Mohican River	448,155

3. Net annual N accumulation - 48,495 kg.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Black Fk., Mohican River	30	925
Unnamed Creek B-1	5	492
Whetstone Creek	11	540

* Estimate based on town of Mifflin (served entirely by septic tanks), 82 shoreline dwellings, one park, and one camp area; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	5.56	0.97	91.0	8.9

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Charles Mill Reservoir:

"Dangerous" (eutrophic loading)	1.08
"Permissible" (oligotrophic loading)	0.54

V. LITERATURE REVIEWED

Burberry, Robert (Supt.), 1974. Treatment plant questionnaire (Shelby STP), Shelby.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Youger, John, 1975. Personal communication (lake morphometry). OH Env. Prot. Agency, Columbus.

_____, 1976. Personal communication (point sources in the drainage area). OH Env. Prot. Agency, Columbus.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
3901	BEACH CITY RESERVOIR	0.122	1.990	489.000	10.867	11.600	0.015
3902	BUCKEYE LAKE	0.179	0.380	490.000	186.567	9.600	0.020
3905	CHARLES MILL RESERVOIR	0.127	0.465	482.555	67.144	15.000	0.011
3906	DEER CREEK RESERVOIR	0.092	2.980	470.125	9.887	13.900	0.036
3907	DELAWARE RESERVOIR	0.084	2.340	484.111	10.856	14.500	0.024
3908	DILLION RESERVOIR	0.163	1.590	481.250	27.400	14.300	0.037
3912	GRANT LAKE	0.113	0.570	486.333	40.533	12.200	0.019
3914	HOOVER RESERVOIR	0.040	1.640	462.750	13.017	14.800	0.008
3915	INDIAN LAKE	0.120	0.380	485.222	76.855	14.200	0.012
3917	LORAMIE LAKE	0.185	1.380	494.000	104.100	8.200	0.019
3921	MOSQUITO CREEK RESERVOIR	0.058	0.150	465.333	36.267	11.600	0.006
3924	PLEASANT HILL LAKE	0.036	0.455	456.833	22.850	14.700	0.010
3927	LAKE SAINT MARYS	0.144	0.200	484.167	79.150	8.200	0.014
3928	ATWOOD RESERVOIR	0.031	0.205	492.300	16.442	14.700	0.005
3929	BERLIN RESERVOIR	0.042	0.400	465.435	15.496	13.600	0.006
3930	HOLIDAY LAKE	0.125	0.575	465.333	55.350	15.000	0.034
3931	JOHNNYCAKE RESERVOIR	0.208	3.070	474.333	5.522	14.900	0.159
3932	ROCKY FORK LAKE	0.067	0.790	473.000	38.022	15.000	0.010
3933	SHAWNEE LAKE	0.069	2.390	474.333	39.567	15.000	0.009
3934	TAPPAN LAKE	0.043	0.240	466.111	37.711	15.000	0.007

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P	INDEX NO
3901	BEACH CITY RESERVOIR	37 (7)	21 (4)	11 (2)	84 (16)	82 (15)	42 (8)	277
3902	BUCKEYE LAKE	11 (2)	76 (14)	5 (1)	0 (0)	89 (17)	26 (5)	207
3905	CHARLES MILL RESERVOIR	26 (5)	63 (12)	37 (7)	21 (4)	11 (0)	58 (11)	216
3906	DEER CREEK RESERVOIR	53 (10)	5 (1)	63 (12)	95 (18)	63 (12)	11 (2)	290
3907	DELAWARE RESERVOIR	58 (11)	16 (3)	32 (6)	89 (17)	47 (9)	21 (4)	263
3908	DILLION RESERVOIR	16 (3)	32 (6)	42 (8)	58 (11)	53 (10)	5 (1)	206
3912	GRANT LAKE	47 (9)	58 (11)	16 (3)	32 (6)	74 (14)	34 (6)	261
3914	HOOVER RESERVOIR	87 (16)	26 (5)	89 (17)	79 (15)	32 (6)	79 (15)	392
3915	INDIAN LAKE	42 (8)	76 (14)	21 (4)	16 (3)	58 (11)	53 (10)	266
3917	LORAMIE LAKE	5 (1)	37 (7)	0 (0)	5 (1)	97 (18)	34 (6)	178
3921	MOSQUITO CREEK RESERVOIR	74 (14)	100 (19)	82 (15)	53 (10)	82 (15)	92 (17)	483
3924	PLEASANT HILL LAKE	95 (18)	68 (13)	100 (19)	63 (12)	39 (7)	66 (12)	431
3927	LAKE SAINT MARYS	21 (4)	95 (18)	26 (5)	11 (2)	97 (18)	47 (9)	297
3928	ATWOOD RESERVOIR	100 (19)	89 (17)	95 (18)	68 (13)	39 (7)	100 (19)	491
3929	BERLIN RESERVOIR	79 (15)	42 (8)	74 (14)	74 (14)	68 (13)	92 (17)	429
3930	HOLIDAY LAKE	32 (6)	53 (10)	82 (15)	26 (5)	11 (0)	16 (3)	220
3931	O'SHAUGNESSY RESERVOIR	0 (0)	0 (0)	47 (9)	100 (19)	26 (5)	0 (0)	173
3932	ROCKY FORK LAKE	68 (13)	47 (9)	58 (11)	42 (8)	11 (0)	66 (12)	292
3933	SHAWNEE LAKE	63 (12)	11 (2)	53 (10)	37 (7)	11 (0)	74 (14)	249
3934	TAPPAN LAKE	87 (16)	84 (16)	68 (13)	47 (9)	11 (0)	84 (16)	381

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	3926	ATWOOD RESERVOIR	491
2	3921	MOSQUITO CREEK RESERVOIR	483
3	3924	PLEASANT HILL LAKE	431
4	3929	BERLIN RESERVOIR	429
5	3914	HOOVER RESERVOIR	392
6	3934	TAPPAN LAKE	381
7	3927	LAKE SAINT MARYS	297
8	3932	ROCKY FORK LAKE	292
9	3906	DEER CREEK RESERVOIR	290
10	3901	BEACH CITY RESERVOIR	277
11	3915	INDIAN LAKE	266
12	3907	DELAWARE RESERVOIR	263
13	3912	GRANT LAKE	261
14	3933	SHAWNEE LAKE	249
15	3930	HOLIDAY LAKE	220
16	3905	CHARLES MILL RESERVOIR	216
17	3902	BUCKEYE LAKE	207
18	3908	DILLION RESERVOIR	206
19	3917	LORAMIE LAKE	178
20	3931	O'SHAUGNESSY RESERVOIR	173

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR OHIO 02/18/76

LAKE CODE 3905 CHARLES HILL RESERVOIR

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 556.8

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
3905A1	562.0	6.99	9.51	12.37	9.32	7.42	4.25	3.68	1.56	0.93	0.99	2.27	4.39	5.28
3905A2	375.5	5.89	6.60	8.78	7.08	4.19	2.63	1.61	0.96	0.82	0.82	1.70	3.37	3.69
3905B1	21.5	0.28	0.37	0.54	0.45	0.25	0.14	0.09	0.04	0.03	0.04	0.08	0.17	0.20
3905C1	43.5	0.59	0.71	1.08	0.88	0.51	0.28	0.18	0.08	0.06	0.08	0.16	0.34	0.41
3905ZZ	116.3	1.78	2.07	2.80	2.27	1.33	0.76	0.48	0.28	0.21	0.22	0.48	1.02	1.14

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 556.8
SUM OF SUB-DRAINAGE AREAS = 556.8

TOTAL FLOW IN = 65.58
TOTAL FLOW OUT = 63.68

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
3905A1	5	73	8.66	5	7.90				
	6	73	13.54	9	13.88				
	7	73	6.43	7	9.83				
	8	73	3.20	5	1.70				
	9	73	0.82	17	0.59				
	10	73	1.76	19	1.30				
	11	73	4.13	19	1.70				
	12	73	11.13	8	8.44				
	1	74	16.80	12	5.52				
	2	74	13.96	10	8.21	27	10.08		
	3	74	17.36	9	15.21	18	28.03		
	4	74	9.34	7	24.78				
3905A2	5	73	6.12	5	3.34				
	6	73	8.98	9	14.22				
	7	73	4.28	7	7.87				
	8	73	2.15	5	1.02				
	9	73	0.59	17	0.34				
	10	73	1.30	19	0.54				
	11	73	3.57	19	1.16				
	12	73	7.45	8	3.65				
	1	74	13.85	12	2.32				
	2	74	5.49	10	3.51	27	4.90		
	3	74	11.50	9	16.20	18	13.05		
	4	74	6.06	7	16.11				

TRIBUTARY FLOW INFORMATION FOR OHIO 02/18/76

LAKE CODE 3905 CHARLES MILL RESERVOIR

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
3905B1	5	73	0.37	5	0.19				
	6	73	0.45	9	0.82				
	7	73	0.23	7	0.45				
	8	73	0.09	5	0.06				
	9	73	0.02	17	0.01				
	10	73	0.06	19	0.03				
	11	73	0.16	19	0.07				
	12	73	0.37	8	0.21				
	1	74	0.68	12	0.13				
	2	74	0.31	10	0.20	27	0.28		
	3	74	0.71	9	0.93	18	0.74		
	4	74	0.40	7	0.93				
3905C1	5	73	0.74	5	0.40				
	6	73	0.96	9	1.64				
	7	73	0.48	7	0.91				
	8	73	0.18	5	0.12				
	9	73	0.05	17	0.02				
	10	73	0.12	19	0.06				
	11	73	0.34	19	0.13				
	12	73	0.76	8	0.42				
	1	74	1.39	12	0.27				
	2	74	0.59	10	0.40	27	0.57		
	3	74	1.42	9	1.87	18	1.50		
	4	74	0.74	7	1.87				
3905ZZ	5	73	1.95						
	6	73	2.61						
	7	73	1.27						
	8	73	0.62						
	9	73	0.15						
	10	73	0.34						
	11	73	1.02						
	12	73	2.27						
	1	74	4.19						
	2	74	1.73						
	3	74	3.68						
	4	74	1.93						

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/01/27

390501
40 46 38.0 082 23 30.0
CHARLES MILL RESERVOIR
39139 OHIO

11EPALES
3

2111202
0006 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/04/20	11	20 0000	14.4	11.8	18	450	8.40	146	0.040	1.100	0.930	0.008
73/07/27	14	25 0000	25.2		12	427	8.10	139	0.170	2.000	0.490	0.018
	14	25 0003	25.2	3.9		416	7.90	139	0.220	1.200	0.680	0.019
73/10/06	11	35 0000	18.8	9.4	12	460	8.30	167	0.060	2.000	0.060	0.018

-24-

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/04/20	11	20 0000	0.052	72.9
73/07/27	14	25 0000	0.189	91.2
	14	25 0003	0.264	
73/10/06	11	35 0000	0.198	86.2

STORET RETRIEVAL DATE 75/01/27

390502
40 45 27.0 082 22 08.0
CHARLES MILL RESERVOIR
39005 OHIO

11EPALES 2111202
3 0023 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/04/20	11	35 0000	14.1		30	410	8.50	132	0.040	0.600	1.200	0.006
	11	35 0006	13.7	14.1		460	8.20	135	0.050	0.500	1.200	0.007
	11	35 0012	12.4	10.9		389	8.80	122	0.040	0.800	0.360	0.007
	11	35 0019	10.7	7.8		390	8.40	122	0.050	1.200	0.400	0.007
73/07/27	14	50 0000	27.1	5.8	15	368	8.70	115	0.070	1.700	0.090	0.010
	14	50 0005	25.8			367						
	14	50 0007	25.2	2.5		370	7.70	118	0.160	1.400	0.100	0.016
	14	50 0010	24.3	0.7		383	7.50	132	0.540	1.900	0.110	0.028
	14	50 0015	19.4	0.0		378	7.40	148	0.880	2.200	0.120	0.014
	14	50 0020	14.0			365						
	14	50 0025	12.2			372						
	14	50 0027	11.9	0.0		378	7.20	192	4.600	7.600	0.120	0.020
73/10/06	11	50 0000	19.7		22	328	7.90	119	0.090	1.400	0.040	0.011
	11	50 0005	19.5	6.6		328	7.90	121	0.070	1.300	0.020	0.012

-25-

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/04/20	11	35 0000	0.038	75.9
	11	35 0006	0.062	
	11	35 0012	0.062	
	11	35 0019	0.067	
73/07/27	14	50 0000	0.138	40.2
	14	50 0007	0.139	
	14	50 0010	0.166	
	14	50 0015	0.185	
	14	50 0027	0.800	
73/10/06	11	50 0000	0.092	49.6
	11	50 0005	0.111	

STORET RETRIEVAL DATE 75/01/27

390503
40 44 29.0 082 21 45.0
CHARLES MILL RESERVOIR
39005 OHIO

11EPALES
3

2111202
0009 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/04/20	12 00	0000	13.7		24	380	8.50	122	0.060	0.800	0.420	0.007
	12 00	0005	12.9	9.7		370	8.90	122	0.150	1.000	0.570	0.006
73/07/27	15 25	0000	26.3	9.4	12	388	8.60	120	0.100	1.600	0.250	0.010
	15 25	0005	25.4	6.8		388	8.10	122	0.150	1.600	0.260	0.011
73/10/06	12 00	0000	19.1	8.4	12	360	8.30	135	0.060	1.500	0.030	0.011

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/04/20	12 00	0000	0.058	41.7
	12 00	0005	0.060	
73/07/27	15 25	0000	0.172	85.5
	15 25	0005	0.187	
73/10/06	12 00	0000	0.117	61.1

APPENDIX E

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 75/02/03

3905A1
40 43 14.0 082 22 25.0
BLACK FORK MOHICAN RIVER
39127 7.5 PERRYSVILLE
O/CHARLES MILL RESERVOIR
ST HWY 603 BRDG 1 MI SSW OF CHARLES MILL
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/05	13 35		0.920	1.600	0.015	0.008	0.095
73/06/09	13 30		1.080	2.000	0.021	0.013	0.125
73/07/07	13 57		0.940	1.890	0.110	0.016	0.150
73/08/05	08 50		0.220	3.400	0.110	0.016	0.185
73/09/17	14 30		0.042	1.320	0.019	0.033	0.165
73/10/19	13 47		0.140	2.000	0.037	0.028	0.140
73/11/19	14 00		0.216	1.000	0.028	0.012	0.240
73/12/08	13 50		2.100	0.850	0.032	0.032	0.110
74/01/12	14 15		2.100	0.900	0.132	0.036	0.105
74/02/10	13 45		2.000	0.800	0.087	0.035	0.080
74/02/27	14 30		1.840	1.000	0.070	0.030	0.120
74/03/09	14 55		1.840	1.200	0.030	0.025	0.160
74/03/18			1.415	1.800	0.123	0.025	0.130
74/04/07	13 50		1.500	1.600	0.055	0.040	0.280

STORET RETRIEVAL DATE 75/02/03

3905A2
40 51 55.0 082 26 24.0
BLACK FORK MOHICAN RIVER
39 7.5 PAVONIA
I/CHARLES MILL RESERVOIR
ST HWY 545 BRDG 1.7 MI SSW OF OLIVESBURG
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/05	14	50	1.400	1.380	0.058	0.056	0.115
73/06/09	14	35	3.700	2.520	0.100	0.087	0.195
73/07/07	15	05	1.800	2.000	0.090	0.066	0.330
73/08/05	10	00	1.040	1.320	0.250	0.058	0.170
73/09/17	14	10	0.960	1.380	0.084	0.058	0.190
73/10/19	13	20	0.840	1.200	0.028	0.071	0.195
73/11/19	13	30	1.120	0.950	0.060	0.104	0.220
73/12/08	14	50	2.400	0.500	0.060	0.052	0.125
74/01/12	15	15	1.520	1.600	0.400	0.064	0.135
74/02/10	15	00	1.680	0.600	0.150	0.045	0.100
74/02/27	14	00	2.200	1.400	0.140	0.050	0.130
74/03/09	15	45	1.900	2.400	0.070	0.050	0.420
74/03/18	13	45	2.200	1.300	0.115	0.060	0.170
74/04/07	14	35	1.900	1.800	0.100	0.055	0.260

STORET RETRIEVAL DATE 75/02/03

390581
40 49 30.0 082 23 46.0
UNNAMED CREEK
39 7.5 PAVONIA
T/CHARLES MILL RESERVOIR
ST HWY 603 BRDG 0.2 MI NW OF FIVE POINTS
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/05	14	10	0.680	0.780	0.017	0.006	0.006
73/06/09	13	55	0.510	0.420	0.008	0.007	0.015
73/07/07	14	17	0.370	0.560	0.017	0.016	0.020
73/08/05	09	10	0.231	2.000	0.108	0.005K	0.010
73/09/17	14	45	0.046	1.320	0.011	0.026	0.170
73/10/19	13	33	0.078	0.550	0.013	0.014	0.014
73/11/19	13	45	1.180	0.550	0.040	0.008	0.008
73/12/08	14	10	1.010	0.800	0.044	0.014	0.030
74/01/12	14	35	1.180	0.200	0.025	0.010	0.015
74/02/10	14	10	1.510	0.800	0.060	0.010	0.010
74/02/27	14	15	1.440	0.700	0.075	0.010	0.030
74/03/09	15	15	0.792		0.090	0.035	
74/03/18	14	55	1.500	0.600	0.070	0.020	0.030
74/04/07	14	05	0.750	0.700	0.040	0.010	0.015

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/03

3905C1
40 52 10.0 082 25 44.0
WHETSTONE CREEK
39 7.5 PAVONIA
T/CHARLES MILL RESERVOIR
VANTILBURG RD BRDG 0.5 MI E OF ST HWY545
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/05	14	55	0.650	1.050	0.019	0.009	0.020
73/06/09	14	21	1.460	0.460	0.021	0.028	0.050
73/07/07	15	00	0.580	1.150	0.110	0.023	0.050
73/08/05	09	27	0.048	1.470	0.110	0.007	0.030
73/09/17	14	05	0.042	0.690	0.044	0.010	0.035
73/10/19	13	20	0.022	1.250	0.056	0.012	0.025
73/11/19	13	35	0.144	0.400	0.028	0.008	0.015
73/12/08	14	45	1.600	0.800	0.036	0.024	0.045
74/01/12	15	05	1.520	0.400	0.048	0.016	0.025
74/02/10	14	55	1.800	0.800	0.060	0.015	0.025
74/02/27	14	05	1.600	0.400	0.035	0.010	0.045
74/03/09	15	30	0.840		0.150	0.095	
74/03/18	14	50	1.700	1.000	0.065	0.025	0.055
74/04/07	14	30	1.180	0.500	0.030	0.019	0.040

1/3-

STORET RETRIEVAL DATE 75/02/03

3905AA AS3905AA P010000
40 54 58.0 082 35 30.0
SHELBY S.T.P.
39 RICHLAND COUNTY
T/CHARLES MILLS RESERVOI
BLACK FORK MOHICAN RIVER
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/08/20	08 00								
CP(T)- 73/08/20	20 00		6.600	12.300	2.720	5.700	6.700	1.200	1.200
73/09/20	08 00								
CP(T)- 73/09/20	18 00		0.075	22.100	11.800		9.500	0.800	0.900
73/10/10	08 00								
CP(T)- 73/10/10	20 00		0.060	18.500	4.800	4.500	5.000	1.000	0.900
73/11/20	08 00								
CP(T)- 73/11/20	18 00		2.940	17.500	3.700	9.900	10.500	0.980	0.920
73/12/18	08 00								
CP(T)- 73/12/18	20 00		6.900	5.700	0.044	6.400	7.000	1.260	1.400
74/01/16	08 00								
CP(T)- 74/01/16	20 00		2.400	14.000	0.040	2.700	7.200	2.700	1.600
74/02/19	08 00								
CP(T)- 74/02/19	20 00		2.080	7.600	0.340	4.600	5.200	1.800	1.600
74/03/21	08 00								
CP(T)- 74/03/21	20 00		0.480	8.000		2.200	3.300	1.800	1.700
74/04/23	08 00								
CP(T)- 74/04/23	20 00		0.240	11.000		2.800	3.300	1.800	1.800
74/05/22	08 00								
CP(T)- 74/05/22	20 00		0.120	23.000	8.500	5.500	7.400	1.600	1.600
74/06/19	08 00								
CP(T)- 74/06/19	20 00		0.036	26.000	8.700	7.650	9.100	1.100	1.100
74/07/22	08 00								
CP(T)- 74/07/22	20 00		0.528	28.000	13.000	9.000	9.600	0.850	0.900

STORET RETRIEVAL DATE 5/02/03

3905AA AS3905AA P010000
40 54 58.0 082 35 30.0
SHELBY S.T.P.
39 RICHLAND COUNTY
T/CHARLES MILLS RESERVOI
BLACK FORK MOHICAN RIVER
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/08/19 CP(T)- 74/08/19	08 00 20 00		0.040	28.000	8.100	6.700	7.500	0.900	1.100